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CASTING PARAMETERS OPTIMIZATION OF ALUMINUM - SCANDIUM LIGATURES BY USING MATHEMATICAL MODELLING METHODS

The abstract of the Master's Thesis

Krasnoyarsk 2017

The work was carried out in the engineering and technological center of RUSAL in the framework of the project "Development of electrolysis technology to produce an Al-Sc alloy"

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INTRODUCTION

Urgency of scientific work. To the mechanical properties of aluminum alloys, ever higher demands are made. The development of new types of alloys and the improvement of the production technology of existing ones is a priority in the foundry industry. To obtain high-quality products from aluminum alloys, doping additives of refractory metals are used, which are added in the form of ingots during the preparation of the melt. There are many ways to obtain and prepare ligatures, depending on the chemical composition and purpose.

The mechanical properties of cast products directly depend on the quality of the melt preparation and casting regimes, including a huge role in this process is played by charge materials. Ligatures of poor quality with a high level of liquation in the volume of the ingot can lead to a heterogeneous coarse-grained structure, which will affect the mechanical properties of the casting, therefore the production of high-quality ingot ingots is an urgent task of modern foundry production.

Subject of research: Development of casting technology for Al-Sc alloy ingots with a high rate of crystallization, evaluation of the structure and chemical uniformity of castings.

The purpose of the work: the creation of the Al-Sc master alloy casting technology with high cooling rate, homogeneous structure and chemical composition.

To achieve the goal the following tasks are solved:

- Creation of a mold for obtaining alloy ingots with a high rate of crystallization;
- Development of a casting regime for the manufacture of ligatures;
- Evaluation of the structure and properties of cast ligatures.

Scientific novelty of the work:

1. A mathematical model of the casting process of alloy ingots was created, which allowed choosing the optimal design for ingot casting.
2. The dependence of the change in the properties of cast ligatures on the content of scandium was experimentally obtained.

Practical importance of the work:

1. The construction of a mold for casting ligatures was developed;
2. The use of mathematical modeling makes it possible to significantly reduce the cost of manufacturing experimental designs of molds for casting ligatures;
3. The results of the studies show that for the casting of ligatures with different scandium content, it is necessary to use different temperatures of the ligature to be poured.
4. The results of the work are used in the implementation of the project "Development of electrolysis technology to produce an Al-Sc alloy."

Personal contribution of the author:

All the results of the research were obtained in co-authorship and with the personal participation of the author, the main of which are: the development of a mathematical model of casting; Processing and analysis of the results of experimental studies of cast ligatures.

Place of the dissertation. Engineering and Technological Center of the United Company RUSAL.
Place of international internship. Company MECAS ESI (Brno, Czech Republic).
Approbation of work. The main provisions of the thesis are presented at the annual congress: International Congress "Non-Ferrous Metals" (Krasnoyarsk, 2014, 2015, 2016).
Publications. The results of the thesis are reflected in 1 article, in the journal included in the list of publications recommended by the Higher Attestation Commission. A decision was made to issue a patent for a utility model (application No. 2016129605/02) filing date on July 19, 2016.
The volume and structure of the dissertation: The dissertation consists of an introduction, 3 chapters and conclusion. Contains 102 pages of typewritten text, 64 drawings, 22 tables, bibliographic list of 32 positions.

CONTENT OF WORK

In the introduction, the relevance of the topic is substantiated and the purpose of the work is formulated, its novelty and practical significance is noted.

In the first chapter, the current trends in the use of ligatures in foundry are discussed, and modern systems of alloys and their applications are also presented. The methods of industrial ligature production have been analyzed, the analysis of modern literature on the properties of Al-Sc alloys has been carried out. Modern methods of computer modeling are considered.

The analysis of scientific and technical literature made it possible to draw the following conclusions:
1. The production of ligatures requires a high level of organization of the technological process, in order to reduce the fumes of alloying components, it is required to reduce the number of technological rework.
2. The most relevant is the production of ligature by electrolysis.
3. For casting alloy ingots, a high superheat of the base alloy and a high rate of crystallization are required, which will allow more complete fixation of scandium in aluminum solution.
4. Modern methods of mathematical modeling provide high convergence of results, however for the development of industrial technologies it is necessary to check models with the help of experimental studies.

The second chapter presents a methodology for mathematical modeling of the non-stationary process of casting and crystallization of a casting ingot. The design of the casting mold for casting ingots and the algorithm of the device operation are described. Using the mathematical apparatus, the heat and mass transfer process is described using the energy conservation equation, and also the system of differential equations for the Newtonian compressible fluid describing the hydrodynamic processes in filling the shape.

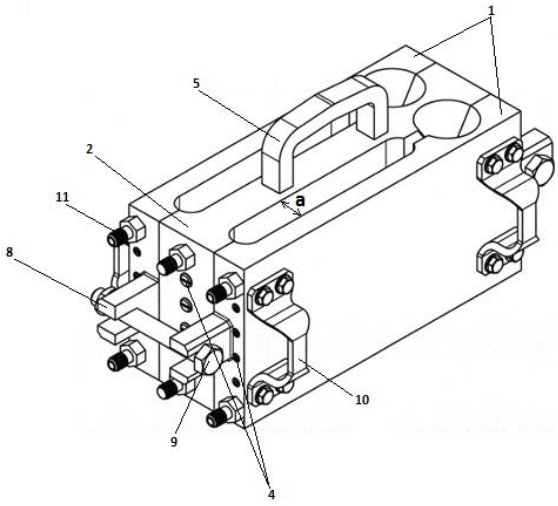

Figure 1 - Construction of a water cooled chill mold.

The result of the numerical simulation is the physical fields of temperature, the crystallization front, the velocity field of filling the mold of the chill mold, and the temperature and speed of water circulation in the cooling channels of the mold. A separate calculation shows the simulation of the grain structure of the casting. Figure 2 shows the results of mathematical modeling.

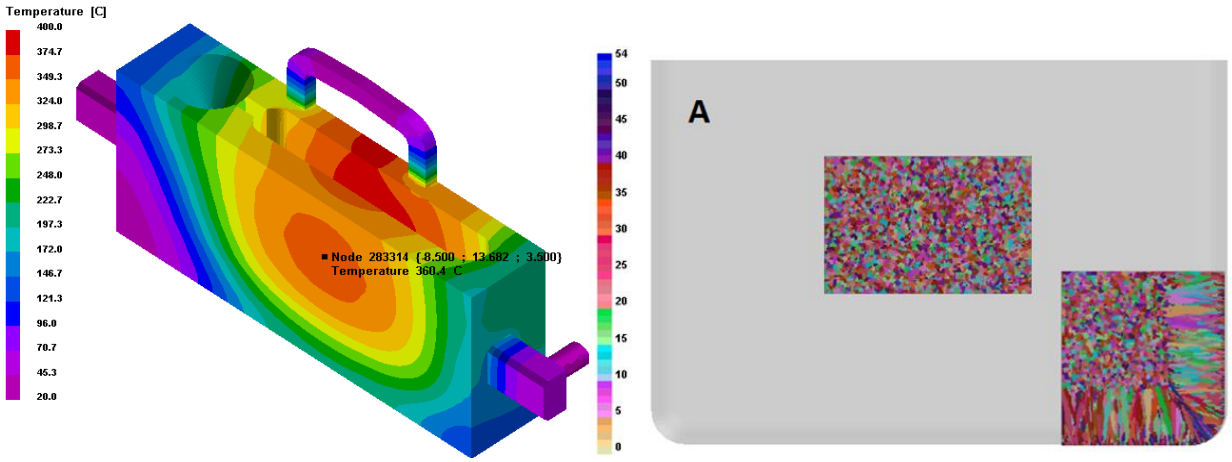

Figure 2 - Results of simulation of the temperature field and the grain structure of the casting.

The third chapter describes the preparation of an experiment on the casting of ligatures with different scandium content of 0.5% to 2%. The definition of scandium in castings is carried out by the classical chemical method in accordance with GOST 11739.25-90, the content of impurity elements was determined on an optical emission spectrometer "Spectromax", and an analysis was also made of the hydrogen content in the casting using the AB-1 gas analyzer. The templates were evaluated using metallographic microscopes "Neophot 21" and "Olympus GX51". The micro hardness was determined on a PMT-3 device. The electrical conductivity was determined with the help of a VE 17NC device. As a result of the analysis of the experiment, the following conclusions are drawn:

1. Ligatures are cast, casting technology is tested;

2. The dependence of the scandium liquation in the casting on its concentration was determined;
3. A certain pattern is established for the reduction of electrical conductivity from the content of scandium in the casting, which can be used to control the chemical composition of the ligature;
4. The results of the experiment confirm the adequacy of the mathematical model.

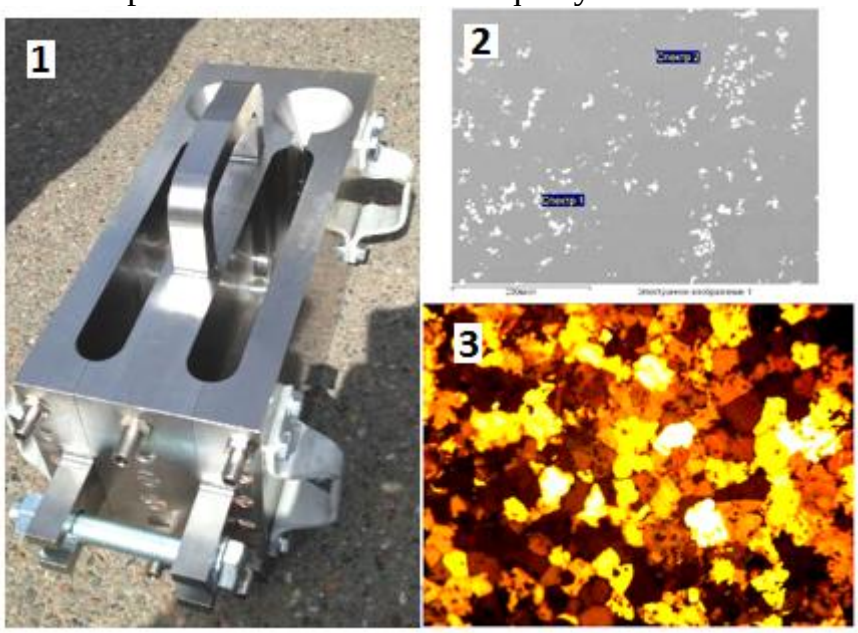

Figure 3 - Die casting mold Al-Sc (1), electron microscopic analysis (2), microstructure of the casting (3).

In conclusion, the main conclusions and results of the work are presented.

MAIN RESULTS AND CONCLUSIONS

1. The technology of casting of Al-Sc alloy ingots has been developed.
2. The use of mathematical modeling made it possible to substantially reduce the costs at the stage of designing and testing the mold.
3. The fine tuning of the mathematical model is determined, which allows to predict the microstructure of the casting from the Al-Sc alloy with high accuracy.

CONCLUSION

The developed Al-Sc alloy casting technology allows to obtain castings of high quality that meet all the requirements of consumers.

BASIC PROVISIONS OF DISSERTATION PUBLISHED IN THE FOLLOWING WORKS

1. Iliin A.A. Investigation of the effect of water cooling of the mold on the temperature field during crystallization of alloy ingots from an aluminum alloy / Zherdev A.S., Vinogradov D.A., Tretyakov Y.A., A.B. Klyuchantsev // Journal of Exploration, №6 2015, Ekaterinburg, from 86- 94.

2. Iliin A.A. Detachable casting mold for casting alloy ingots for aluminum alloys / Mann V.Kh., Pingin V.V., Vinogradov D.A, Tretyakov Y.A., Kuzubov D.V. // The decision to grant a patent for a utility model (Application No. 2016129605/02) filing date on July 19, 2016.